Effect of the Plant Growth Regulator Parlay on the Seed Production of the White Clover cvs. Menna and Olwen
II. Yield Components and Potential Seed Yield

A.H. Marshall and D.H. Hides[1]

ABSTRACT

The influence of the plant growth regulator Parlay (Paclobutrazol) on the seed yield components of two white clover cultivars was assessed under field conditions. Parlay increased the number of harvestable inflorescences (brown plus ripe) and potential seed yield in both harvest years but the total number of inflorescences in 1987 only. Defoliation increased the total number of harvestable inflorescences in both years but seed yield in 1987 only. There were also cultivar differences, the large leaved cv. Olwen having significantly more inflorescences than the medium leaved cv. Menna in 1988 but not in 1987. However, cv. Menna had significantly more harvestable inflorescences in 1987, and cv. Olwen in 1988. The effectiveness of Parlay was also influenced by application date but its effect was not influenced by prior defoliation.

Individual seed yield components were also influenced by Parlay with seed yield per inflorescence and 1000 seed weight increased in both years and seed set per floret in 1988 only. Defoliation had no effect on any of the seed yield components. There were, however, cultivar differences. In 1988 cv. Olwen gave a significantly higher seed yield per inflorescence, seed set per floret and florets per inflorescence than Menna. Generally Parlay had a positive effect on these yield components when applied in April and less effect in May. Seed germination was also increased by Parlay but not affected by any other parameter. The relationship between seed yield components and potential seed yield and use of Parlay in commercial seed production is discussed.

Additional index words: **white clover, *Trifolium repens*, plant growth regulator, Parlay, seed production, seed yield components.**

INTRODUCTION

A previous paper has described the problems associated with producing white clover seed in the United Kingdom, and shown the effect of the plant growth regulator Parlay (PP333, Paclobutrazol) on stolon growth and development in the field (Marshall and Hides, 1991). This has confirmed evidence from glasshouse experiments (Marshall and Hides, 1987) that Parlay applied at a rate of 1.0 kg a.i. ha^{-1} can modify stolon growth in such a way as to increase the number of nodes per unit area without influencing stolon density. The influence of these changes in stolon growth on white clover seed production depends, however, upon the response of individual seed yield components. The number of inflorescences per unit area is determined by the proportion of stolon nodes that become reproductive, whilst seed yield per inflorescence is determined by the number of florets per inflorescence, seed set per floret and 1000 seed weight. Seed quality is also critical as the use of any chemical on seed crops has to be considered in relation to possible detrimental effects on seed germination.

White clover seed crops are normally defoliated in spring to promote flowering and minimise the bulk of green leaf which can reduce pollination and cause problems at harvest (Zaleski, 1964). However, since Parlay is soil acting (Froggatt, Thomas and Batch, 1982) application of Parlay after defoliation may also improve its penetration to the soil and facilitate root uptake.

A previous field experiment has already highlighted the potential of Parlay for white clover seed crops (Marshall and Hides, 1986). This paper describes how the seed yield components of white clover cultivars are influenced by application of Parlay at different developmental growth stages and the interaction with defoliation and season.

MATERIALS AND METHODS

The design of the experiment and the treatments applied were described in a previous paper (Marshall and Hides, 1991), as was a summary of the prevailing weather conditions during the critical period of seed crop development. At approximately weekly intervals between 12 June and 13 July 1987 and 6 June and 27 July 1988, randomly sited 0.25 m^{-2} quadrats were harvested to ground level with hand shears and inflorescences counted in the laboratory. These were used to monitor the pattern of inflorescence production and identify when numbers of ripe inflorescences were approaching a maximum, and therefore the optimum harvest date. At this optimum harvest date (23 July 1987 and 8 August 1988), all inflorescences from within the harvested quadrat were counted and categorised as described previously (Marshall, Hollington and Hides, 1989). As the

[1]AFRC Institute of Grassland and Environmental Research, Welsh Plant Breeding Station, Plas Gogerddan, Aberystwyth, Dyfed SY23 3EB, U.K. Received for publication 19 February 1991.

proportion of brown inflorescences at harvest that contribute to harvestable yield depends upon the method of harvest (Marshall, Hollington and Hides, 1989), in this experiment, ripe plus brown inflorescences were classified as harvestable. Further analysis was therefore carried out on ten ripe and brown inflorescences selected at random from each of the harvested quadrats. These were dissected and a count made of the number of florets per inflorescence. The florets from each sample were then pooled and the seed rubbed out; the total yield of seed from the same was then weighed and number of seeds counted. From these, seed set per floret and per inflorescence and thousand seed weights were calculated. As practical difficulties prevented actual seed yields being obtained, the seed yield potential was calculated from the measured components.

Germination was tested by placing 25 seeds on moist filter paper (Whatman No. 4) in a petri dish. Four replicated dishes were placed in seed trays and sealed in a polythene bag. After incubation at 20°C for 14 days the number of germinating seeds was counted.

RESULTS

Inflorescence production

Parlay significantly increased the total number of inflorescences at harvest in 1988, but not in 1987, and of harvestable (brown plus ripe) inflorescences in both years (Table 1). There were also significant Parlay x application date interactions. In 1987 Parlay applied in April reduced ($P < 0.05$) inflorescence production (511 m^{-2}) compared to the untreated control (655 m^{-2}) but when applied in May (703 m^{-2}) increased ($P < 0.05$) it compared to the control (562 m^{-2}). In 1988 however, Parlay applied in April increased ($P < 0.05$) inflorescence production (1082 m^{-2}) compared to the control (715 m^{-2}) but had no effect when applied in May. Defoliation also increased the total and the number of harvestable inflorescences in both years (Table 1). There were also significant cultivar differences. Cv. Olwen produced more ($P < 0.05$) inflorescences than cv. Menna in 1988 but not 1987, although cv. Menna had significantly more harvestable inflorescences than cv. Olwen in 1987 and cv. Olwen more than cv. Menna in 1988. There were no significant Parlay x defoliation interactions. There was, however, a significant Parlay x cultivar interaction in 1988, but not 1987. In 1988, Parlay increased ($P < 0.05$) the number of harvestable inflorescences of cv. Olwen (829 m^{-2}) compared to the control (516 m^{-2}) but not for cv. Menna. There were no other significant interactions.

Seed yield components

Overall, and in both harvest years, Parlay significantly increased seed yield per inflorescence and 1000 seed weight (Table 2). However, while seed set per floret was low in both years it was significantly increased by the application of Parlay while the number of florets per inflorescence was significantly reduced (Table 2) in 1988 but not in 1987. There was also a significant Parlay x

Table 1. Effect of Parlay, defoliation and cultivar on inflorescence production at harvest.

	Total inflorescences m^{-2}		Brown + ripe (harvestable) inflorescences m^{-2}	
	1987	**1988**	**1987**	**1988**
Chemical				
No chemical	611	651	349	472
Chemical	607	853	450	622
LSD (P = 0.05)	NS	113	89	97
Defoliation				
No cut	534	684	316	487
Cut	684	820	482	607
LSD (P = 0.05)	74	113	89	97
Cultivar				
Menna	650	670	442	420
Olwen	568	834	356	674
LSD (P = 0.05)	NS	125	58	103

application date interaction in 1988, as Parlay increased ($P < 0.05$) seed yield per inflorescence (0.065 g) compared to the control (0.038 g) and seed set per floret (1.9) compared to the control (1.2) when applied in April but not in May, and increased ($P < 0.05$) the number of florets per inflorescence (59.8) compared to the control (45.6) when applied in May but not in April. There was also a significant cultivar difference (Table 2) whereby cv. Olwen had a higher seed yield per inflorescence, seed set per floret and more florets per inflorescence in 1988 but not in 1987.

There was a significant Parlay x cultivar interaction in 1987, but not 1988, since Parlay increased ($P < 0.05$) the 1000 seed weight of cv. Menna (0.66 g) compared to the control (0.56 g) but not cv. Olwen. Defoliation had no significant effect on any seed yield component and there were no other significant interactions.

Potential seed yield

Potential seed yields in both harvest years were significantly increased by the application of Parlay (Table 3). There was, however, no significant Parlay x application date interaction. Defoliation also increased ($P < 0.05$) potential seed yield in 1987 but had no effect in 1988. There was no significant effect of cultivar in 1987; however, in 1988, cv. Olwen had a higher ($P < 0.05$) seed yield than cv. Menna. The effect of Parlay was not influenced by defoliation or cultivar but in 1988 Parlay significantly increased the potential seed yield of cv. Olwen (578 kg ha^{-1}) compared to the control (205 kg ha^{-1}) but not of cv. Menna. Potential seed yields were also higher when Parlay was applied in April (509 kg ha^{-1}) than in May (205 kg ha^{-1}) compared to the controls (245 and 110 kg ha^{-1} respectively).

Table 2. Effect of Parlay (chemical) and cultivar on seed yield components.

	Seed yield/ inflorescence (g)		1000 seed weight (g)		Florets/ inflorescence		Seed set/floret	
	1987	1988	1987	1988	1987	1988	1987	1988
Chemical								
No chemical	0.016	0.036	0.60	0.54	46.8	57.8	0.6	1.1
Chemical	0.026	0.047	0.66	0.60	49.1	51.3	0.8	1.5
LSD (P = 0.05)	0.007	0.008	0.03	0.03	NS	4.7	NS	0.3
Cultivar								
Menna	0.019	0.031	0.61	0.57	45.8	50.0	0.7	1.1
Olwen	0.025	0.052	0.65	0.58	50.2	59.2	0.7	1.5
LSD (P = 0.05)	NS	0.01	NS	NS	NS	6.7	NS	0.3

Seed quality

Percentage seed germination was significantly increased by Parlay in both years but was not influenced by cultivar, date or defoliation (Table 4). In 1987 only there was a significant Parlay x cultivar interaction, Parlay increasing germination of cv. Menna but not of cv. Olwen (Table 4). There were no other significant interactions in either year.

DISCUSSION

A previous glasshouse study (Marshall and Hides, 1987) has shown how the plant growth regulator Parlay can modify stolon growth and development in ways likely to increase inflorescence production and potential seed yields. These results show that in both harvest years Parlay increased potential seed yields by increasing inflorescence production, number of harvestable inflorescences, seed yield per inflorescence and 1000 seed weight, and in 1988 only, seed set per floret. Overall, potential seed yields were increased from 63 kg ha^{-1} to 126 kg ha^{-1} in 1987 and from 179 kg ha^{-1} to 356 kg ha^{-1} in 1988 by the application of Parlay. These increases of close to 100% illustrate the potential for increasing white clover seed yields using the plant growth regulator Parlay. The higher potential seed yields in 1988 can be attributed principally to more harvestable inflorescences and also higher seed yield per inflorescence due to more seeds per floret and more florets per inflorescence. Inflorescence production has been shown to respond positively to high temperatures (Norris, 1985), and June 1988, when most inflorescences were being produced, was drier and warmer and had more hours of sunshine than in 1987 (Marshall and Hides, 1991). Such conditions may also limit floret abortion (Clifford, 1987) and increase bee density and consequently increase seed set. The lower 1000 seed weight in 1988 can be attributed to the fact that once ovules are fertilised they are retained at the expense of provisioning (Clifford, 1987).

Table 3. Effect of Parlay (chemical), defoliation and cultivar on potential seed yield (kg ha^{-1})

	Potential seed yield (kg ha^{-1})	
	1987	**1988**
Chemical		
No chemical	63	179
Chemical	126	356
LSD (P = 0.05)	41	66
Defoliation		
No cut	62	235
Cut	126	300
LSD (P = 0.05)	41	NS
Cultivar		
Menna	97	143
Olwen	92	392
LSD (P = 0.05)	NS	93

Table 4. Effect of Parlay (chemical) on the germination (%) of white clover cvs. Menna and Olwen.

	1987			**1988**		
	Menna	**Olwen**	**mean**	**Menna**	**Olwen**	**mean**
No chemical	75.2	77.6	76.4	73.0	65.5	69.3
Chemical	86.8	80.2	83.5	80.0	79.8	79.9
Mean	81.0	78.9		76.5	72.6	
LSD (P = 0.05)						
Cultivar		NS			NS	
Chemical		4.3			3.4	
Cultivar x chemical		4.3			NS	

Inflorescence production was the main seed yield component increased by Parlay, confirming evidence from other field experiments (Hollington, personal communication). This was achieved by a significant increase in the number of nodes per unit area and reproductive nodes per stolon (Marshall and Hides, 1991). Inflorescence production was also increased by defoliation which has been observed in some (Clifford, 1985) but not all (Hollington, personal communication) previous experiments, although it had little effect on the other seed yield components. Defoliation has been reported to increase inflorescence production by stimulating nodes to become reproductive (Thomas, 1981). There was, however, no increase in the number of reproductive nodes per primary stolon (Marshall and Hides, 1991) suggesting that the response to defoliation may be to stimulate flowering on secondary or tertiary stolons. The timing of this defoliation can also be critical (Clifford, 1985) as removal of developing buds can reduce inflorescence size. Defoliation had no effect on inflorescence size in this experiment, possibly because the defoliation treatment was applied at a time and height that prevented removal of inflorescence buds.

It was of interest to note that Parlay reduced the number of florets per inflorescence in 1988. Visual observation of the plots showed that leaf size was generally reduced by Parlay. Clifford (1987) has shown that leaf size is related to inflorescence size and thus managements which reduce leaf size tend to produce smaller inflorescences.

Reduced inflorescence size in 1988 was, however, more than compensated by the increased inflorescence production, resulting in significantly increased potential seed yields. It is not clear why this effect of Parlay was only observed in 1988 as there was a significant effect on reducing leaf size and increasing inflorescence production in both years.

Cultivar differences arose primarily because cv. Olwen produced significantly more inflorescences in 1988, more harvestable inflorescences in both years and a higher seed yield in 1988. In 1988 cv. Olwen also had more florets, significantly higher seed set and a higher weight of seed per inflorescence. These cultivar differences are not unexpected, since cv. Olwen was bred for enhanced seed yield (Evans, Williams and Davies, 1986) with increased inflorescence size an important factor. The cause of the differences between years is however unclear. Generally, cultivars responded similarly to Parlay which is important as techniques developed for use commercially should ideally be applicable to a wide range of white clover cultivars.

The overall effect of date of Parlay application was variable and differed between years, emphasising the unpredictability of this chemical. In 1987 Parlay increased inflorescence production when applied in May. In 1988, however, Parlay increased inflorescence production and seed set and seed yield per inflorescence when applied in April but reduced florets per inflorescence when applied in May. Parlay is soil acting (Froggatt *et al.*, 1982) and taken up by the roots. Earlier work on perennial ryegrass (Hampton and Hebblethwaite, 1984) has shown that rainfall in the month after application is essential if the effect of Parlay is to be observed. In this experiment, the relatively dry May following April application in 1987 and dry June following May application in 1988 might explain why the application of Parlay in these months was less successful. In contrast, application of Parlay in May 1987 was followed by a wet June whilst application in April 1988 was followed by a wet May, possibly explaining the success of Parlay when applied at these dates. The effect of application date also differed from that seen in glasshouse experiments (Marshall and Hides, 1987), where Parlay appeared to have most effect when applied at the transition of the growing point to the reproductive phase and less effect at later dates, which correspond to the two dates used in this experiment. It was, however, noted that in these glasshouse experiments, application date was confounded with growth stage of the plants, as on later dates there was a shorter time between spraying and data collection. These field experiments suggest that later applications may be as effective if climatic conditions are suitable.

In 1988 Parlay significantly increased inflorescence production and potential seed yield of cv. Olwen but not cv. Menna and the reasons for this are also not clear. Seed set was also increased by Parlay in 1988 and this may be related to the effect on petiole and peduncle height. Parlay reduced petiole and peduncle height, elevating inflorescences above the leaf canopy (Marshall and Hides, 1991). This may have enhanced pollination and therefore increased seed set in this year, but it is unclear why seed set was not increased in both years, as Parlay had a significant effect on petiole and peduncle height in both years. Seed set was generally lower in 1987 but was also less in 1988 than previously reported. This was also reflected in the potential seed yields which in both years were lower than in other field experiments (Marshall and Hides, 1986). This may be attributed to the fact that hives were not placed in the experimental area, so that pollination was dependent upon the wild bee populations which may have differed from other years and been insufficient to adequately pollinate the crop.

The use of any chemical applied to seed crops has to be considered in relation to possible detrimental effects on seed quality. Parlay had no negative effects on seed germination and is therefore appropriate for white clover seed crops.

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